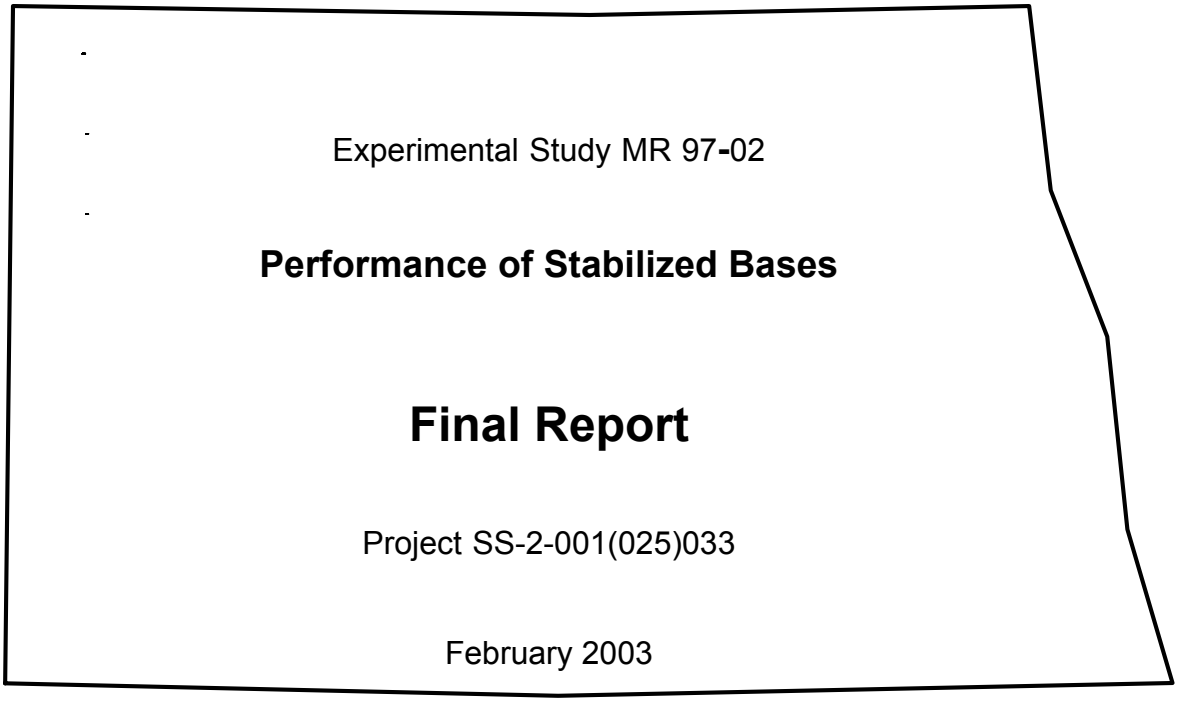
NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION



Experimental Study MR 97-02

Performance of Stabilized Bases

Final Report

Project SS-2-001(025)033

February 2003

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA
Website:http://www.discovernd.com/dot

DIRECTOR
David A. Sprynczynatyk, P.E.

MATERIALS AND RESEARCH DIVISION
Ron Horner

Experimental Study MR 97- 02

Performance of Stabilized Bases

Final Report

Project SS-2-001(025)033

February 2003

Written by
Bryon Fuchs

Disclaimer

The contents of this report reflect the views of the author or authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not reflect the official views of the North Dakota Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

Performance of Stabilized Bases

Objective

Most of the state's flexible pavement systems have been constructed using aggregate base laid on the existing or prepared subgrade and paved with Hot Bituminous Pavement (HBP). Today, new pavements must withstand more traffic and heavier loads when compared to earlier pavements.

If a roadway base layer section can be made stronger by stabilization, thickness of the hot bituminous pavement layer could conceivably be decreased or performance of the roadway increased.

The objective of this study was to determine if stabilizing the base material would significantly increase the structural value of the pavement section and improve long term performance of the roadway.

Scope

In 1998, the North Dakota Department of Transportation (NDDOT) constructed an experimental test section that utilized different stabilizing agents in the base section on one of their projects.

The NDDOT evaluated this test section for a period of 5 years. The following items were evaluated:

- ⇒ Distresses in the pavement.
- ⇒ Overall pavement condition.
- ⇒ Crack pattern in the different base sections.
- ⇒ Performance of each section.
- ⇒ Effect on rutting in the stabilized base sections.
- ⇒ Ride characteristics.
- ⇒ Base strength as determined by the Falling Weight Deflectometer (FWD).

Location

The experimental section was incorporated into project SS-2-001(025)033. The project was located on ND Highway 1 between its intersection with ND 13 on the south end and ND 46 on the north end. Please refer to Figure 1.

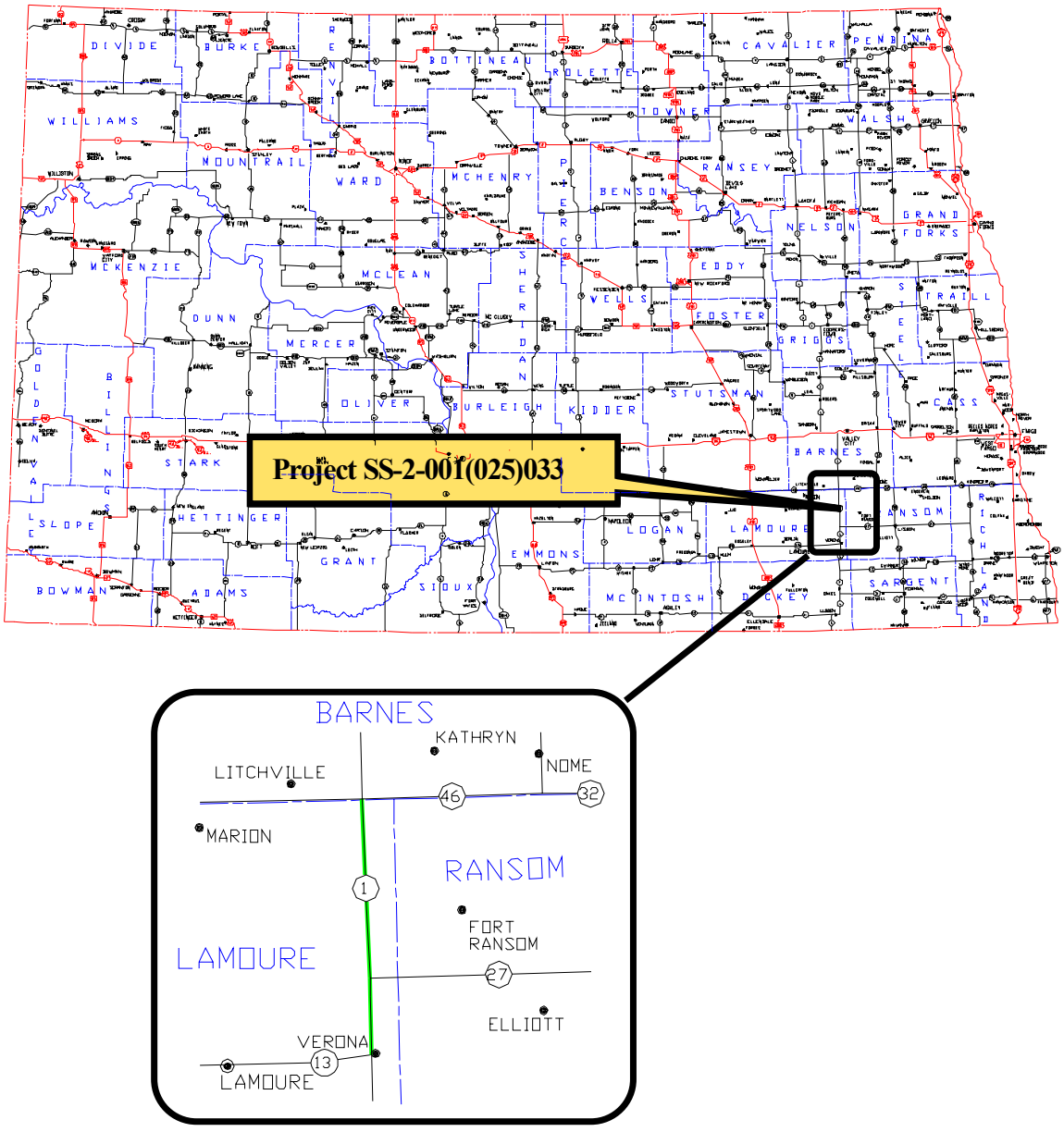


Figure 1. Project Location.

Design

Three different experimental sections were designed. Each section utilized a different product to stabilize the base section. The three products used were; lime, cement, and Consolid. A fourth section was constructed without stabilizers and was used as the control section. The length of each section was 1,500 feet.

Each section was constructed with fourteen inches of aggregate base and 4-1/2 inches of HBP.

Table 1 gives the application rates of the various stabilizing agents used and the reference points for each section.

Stabilizing Agent	Reference point		Design and Construction Application Rate
	From	To	
Lime	43.863	44.147	3% by weight
Cement	44.147	44.431	4% by weight
Consolid	44.431	44.716	0.03 gallons per Square Yard
Control	44.716	45.000	———

Table 1

Density of the blended base was estimated at 130 lbs/ft^3. Consolid was incorporated into the base as recommended by the manufacturer.

Traffic

Two-way traffic for Highway 1 from ND 27 to ND 46 is shown in Table 2.

Year	Passenger	Trucks	Total	30th Max Hour	Flexible ESAL's
1996	430	140	570	70	130
2002	280	150	430	45	125

Table 2

Construction

Project SS-2-001(025)033 started on June 3, 1997 and finished in the fall of 1997. The contractor was Mayo Construction Company, Inc. located in Cavalier, ND. The experimental section containing cement was constructed on June 25, 1997 and the Consolid and lime sections were constructed on June 26, 1997.

Photo 1 - Mining road in area of experimental section.

The cement section was completed with no problems associated with the material or the constructability of the section. The cement was placed on top of the existing mined material and mixed in-place with the mining machine. The material was then bladed to centerline for further mixing and laydown. Water was added as required for laydown and compaction. Compaction was accomplished with a rubber tire roller.

Photo 2 - Placing cement on blended base.

Photo 3 - Blending cement into blended base.

The Consolid section was completed with no major problems. The liquid material was blended with the base by using the mining machine. The contractor noted that this product was easy to work with. The material was compacted in layers because the

manufacturer's representative did not think adequate density could be achieved in one lift. The contractor stated that placing the material in lifts was not part of his bid. But there was no change orders regarding this matter.

Photo 4 - Placing Consolid on blended base.

Photo 5 - Consolid after laydown.

Photo 6 - Blending Consolid into blended base.

The lime section was completed with only minor problems associated with the material and the constructability of the section. Due to the light weight of the material, the material would tend to push out in front of the mining machine. The material also tended to blow away. Water was added as required for laydown and compaction.

Photo 7 - Lime after laydown.

Photo 8 - Blending lime into the blended base.

Photo 9 - Note the dust created during the blending operation of the lime section.

All sections were constructed according to the plans and specifications. Refer to Table 3 for the location and price per square yard for adding a stabilizing agent to the base section. Calculations are based on the bid price for the stabilizing agent.

Stabilizing Agent	Reference point		Application Rate	Price per Square Yard
	From	To		
Lime	43.863	44.147	3% by weight	$2.50
Cement	44.147	44.431	4% by weight	$3.33
Consolid	44.431	44.716	0.03 gallons per Square Yard	$2.73
Control	44.716	45.000	———	———

Table 3

Evaluation

On September 9, 2002, Materials & Research Division conducted the final evaluation on this experimental project. The following parameters were evaluated:

- ⇒ Distresses in the pavement.
- ⇒ Overall pavement condition.
- ⇒ Crack pattern in the different base sections.
- ⇒ Performance of each section.
- ⇒ Effect on rutting in the stabilized base sections.
- ⇒ Ride characteristics.
- ⇒ Base strength as determined by the Falling Weight Deflectometer (FWD), (FWD was performed on August 19, 2002).

Distresses in the Pavement

The only distress noted in the control section and test sections were transverse cracks. Please refer to Table 4.

Section	Number of Transverse Cracks October 16, 2001	Number of Transverse Cracks September 9, 2002
Lime	1	3
Cement	3	5
Consolid	0	2
Control	1	3

Table 4

Referring to Table 4, the only notable section is the cement section. This section has the highest transverse crack count out of the four sections. By adding cement to the aggregate base, the base takes on several properties of concrete, one being more susceptible to cracking. However, these cracks have not affected the ride.

Overall Pavement Condition

The overall pavement condition in each section is very good.

Photo 10 - Base section stabilized with lime, looking north.

Photo 11 - Base section stabilized with cement, looking south.

Photo 12 - Base stabilized with Consolid, looking north.

Photo 13 - Base section with no stabilization, looking south.

Crack Pattern

The only cracks that have appeared are transverse cracks. The cracks are randomly spaced with no set pattern or location. Photo 14 shows a typical transverse crack which is located in the cement stabilized base section.

Photo 14 - Typical transverse crack.

Performance

Each section is performing excellent at this time. The cement section has more transverse cracks than the other sections, however, this has not affected the overall performance of the cement section at this time.

Rutting

No rutting has occurred in the test sections or the control section. Each section is performing equally in this area.

Ride Characteristics

The ride remains excellent in each section. The transverse cracks have not affected the ride. The transverse cracks are not depressed at this time which would affect the ride characteristics.

FWD

The results of the FWD analysis shows the biggest difference in the performance of each material. FWD analysis was performed in August 2000, September 2001, and August 2002. Refer to Table 5 for the analysis.

Referring to Table 5, the lime and cement section are performing fairly close in base strength, more than doubling the base modulus over the control section. The Consolid section has not improved the base strength over the control section at all.

Section	Base Modulus (ksi)			
	August 8, 2000	September 26, 2001	August 19, 2002	Average
Lime	88	90	92	90
Cement	88	106	102	99
Consolid	36	41	36	38
Control	39	41	40	40

Table 5

Pavement Design

Based on the average base modulus for each section in Table 5, a new pavement section was designed for each test segment. Costs were also calculated for the new pavement sections. Refer to Table 6.

Section	Min Aggregate Base Thickness	HBP – Class 29	Cost (SY)	Aggregate Base	Min HBP Thickness Cl. 29	Cost (SY)
Lime	9”	4.5”	$12.49	12”	3.0”	$11.81
Cement	9”	4.0”	$12.25	11”	3.0”	$11.88
Consolid	14”	4.5”	$15.45	14”	4.5”	$15.45
Control	14”	4.5”	$12.72	14”	4.5”	$12.72

Table 6

The costs from Table 6 only include Class 5 aggregate, stabilizing agent (if any), Class 29 aggregate, and PG 58-28 oil. All costs were obtained from the 2002 average annual bid prices except the stabilizing agents, which used the 1997 bid prices. Costs associated with traffic control, additional aggregate or milling due to a mine/blend, widening, testing, or other items are not included.

Based on the above costs and a 30 foot wide road, approximately $4,048 to $16,016 could be saved per mile by utilizing a stabilizing agent depending on the base and HBP thickness used and also depending on the stabilizing agent used. The savings may be more substantial if the reduced section due to stabilization required less embankment material for widening. However, long term maintenance costs are unknown.

The Consolid section has not improved the performance of the base section and we would only see an increase associated with using this material.

Summary

Each section is performing excellent. No distresses are noted in each section except for a few transverse cracks. The ride and overall pavement condition remains excellent and no rutting was evident in the test sections.

The most notable difference in performance of the base sections is the base modulus strengths. The lime and cement sections have at least twice the base strength of the control section. However, the light weight of lime created problems during construction. The Consolid section has the same base strength as the control section.

By using a stabilizing agent, costs may be reduced by reducing the amount of material required for the pavement section and embankment material for widening.

Recommendation

It is recommended on a future project, primarily in an area with limited aggregate resources, that designs be considered utilizing the findings in this report and also utilizing current design methodologies to calculate if there will be an actual construction cost saving. Estimated costs given in Table 6 indicate that prices are comparable so the benefit would primarily be reducing aggregate consumption. However, long term costs associated with maintenance are not known.

It is also recommended that a future research project be performed with fly ash as a stabilizing agent. Class C fly ash has many of the same properties of cement but at a lower cost. The research project could be conducted in phases, with phase I being laboratory testing on the percentage of fly ash required to obtain the same results at the cement stabilized base in this project. Future phases would only proceed with positive results of phase I.

Appendix A

DESIGN DATA - ND 13 TO ND 27				
Traffic	Average Daily			Est.Max.Hr.
Current 1997	Pass:680	Trucks170	Total 850	110
Forecast 2017	Pass:880	Trucks220	Total1100	140
Minimum Sight Dist. for:		Design Speed 60 MPH		
Stopping 475'		Bridges		
Safe Passing 2300'				
Passing for Marking 1100'				

DESIGN DATA - ND 27 TO ND 46				
Traffic	Average Daily			Est.Max.Hr.
Current 1997	Pass:430	Trucks140	Total570	70
Forecast 2017	Pass:560	Trucks180	Total740	90
Minimum Sight Dist. for:		Design Speed 60 MPH		
Stopping 475'		Bridges		
Safe Passing 2300'				
Passing for Marking 1100'				

JOB# 13

FHWA REGION	STATE	PROJECT NO.	SHEET NO.
8	ND	SS-2-001(025)033 I-2-J001-94292	1

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

FEDERAL AID PROJECT SS-2-001(025)033 & I-2-J001-94292
IN LAMOURE COUNTY
BLENDED BASE AND HOT BITUMINOUS PAVEMENT

GOVERNING SPECIFICATIONS:

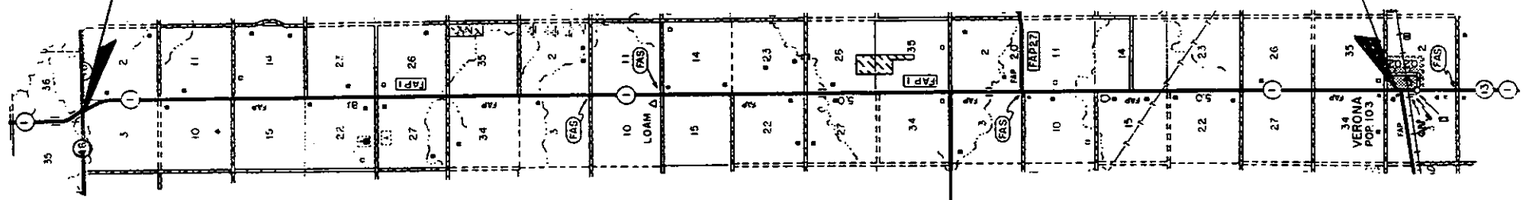
Standard Specifications adopted by the North Dakota Department of Transportation September 1992: Standard Drawings currently in effect; and other Contract Provisions submitted herein.

LENGTH OF PROJECT

18.366 Miles

BEGIN PROJECT SS-2-001(025)033
716.6' East of SW Corner Sec 36.
TWP 137 N. Rge 59 W
Sta 477+45.9

END PROJECT SS-2-001(025)033
Sec 2. Twp 133 N. Rge 59 W
Sta 333+06



EQUATION
1114+13.3 Bk=
0+00 Ahd

DESIGN SECTIONS Brian Rain
George Stefanski
RECOMMEND APPROVAL 1-29, 1997
DESIGN ENGINEER:
K H E Bird

APPROVED DATE 1-30-97
Ray Zink
DIRECTOR OF HIGHWAYS AND ENGINEERING
NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

RAY ZINK REGISTERED PROFESSIONAL P.E. 972 ENGINEER NORTH DAKOTA

r:\project\20001033.025\d_paving\t Jan. 24, 1997 16:09:45

FHWA REGION	STATE	PROJECT NO.	SHEET NO.
8	ND	SS-2-001(025)033	3

REVISED 03/10/1997

202 P01 REMOVAL OF STRUCTURE: This work shall consist of removing the existing bridge on the approach being obliterated near the junction of ND 46 and ND 1

230 P01 SUBGRADE PREPARATION-TYPE A-12 IN: A quantity of 100 Stations has been provided to be used to dry out the subgrade prior to final placement of the blended base at locations determined by the engineer.

203 P02 APPROACH INSLOPE RECONSTRUCTION: The cost of labor, equipment, and materials to perform the following work will be included in the price bid for "Approach Inslope Reconstruction."

1) Strip and stockpile three inches of topsoil from the embankment and excavation areas.
2) Flatten the approach inslopes steeper than 4:1 to 8:1. The material used to flatten the slope will be compacted in accordance with Section 203.02 I of the Standard Specifications. When available the embankment material may be obtained within the R/W in locations approved by the engineer. Embankment not available within the right of way will need to be obtained from borrow. The contractor shall furnish the borrow. The cost of obtaining the site and the borrow shall be included in the price bid for "Approach Inslope Reconstruction."
3) Replace the topsoil on both the excavation and embankment areas and seed with Class II seed Mixture in accordance with Section 708.02 of the Standard Specifications.

Payment will be made for each approach inslope that is flattened. For example, if both inslopes of an approach are flattened, two units will be measured and paid for.

302 P01 BLENDED BASE COURSE: The Blended Base Course shall consist of a uniform blend of the existing surfacing and most of the existing base material. The Blended Base shall be compacted in accordance with Section 302.04.E of the Standard Specifications. Surface tolerance shall be in accordance with Section 302.04.G of the Standard Specifications.
All blended base areas will be left in a condition to carry traffic at the end of each work day. Material on the roadway left in windrows or in any other manner which will obstruct the roadway traffic will not be allowed.
If material has to be left on the roadway do to unforeseen circumstances the contractor will be required to provided the necessary traffic control 24 hours a day at no cost to the Department.
The unit price for the Blended Base Course shall include all costs for sizing, blending, placing and compacting.

302 P02 EXPERIMENTAL SECTIONS: Experimental base sections shall be placed at the following locations:

Stabilizing Agent	Stationing From	Stationing To	Application Rate
Lime	875+66	860+66	3% by weight
Cement	860+66	845+66	4% by weight
Consolid	845+66	830+66	0.03 gals/sq yd
Control	830+66	815+66	

There is no substitution for the product called Consolid. Consolid is to be applied according to manufactures recommendations and shall be bid as "Liquid Base Stabilizer." Contact person for Consolid is:

Don Van Dyke
9077 West Cross Drive
20-201
Littleton, Co 80123
Phone (303)972-7007

All costs to provide and mix the stabilizing agents (including water and emulsion) shall be included in the unit price bid for "Hydrated Lime", "Liquid Base Stabilizer", and "Portland Cement."

408 P01 HOT BIT MIX SUPPLIED(I-2-J001-94292): A quantity of 9000 ton of Hot Bit Pvmt-Cl 27 shall be loaded in state maintenance trucks at the plant site. The engineer and the contractor will coordinate so there is the least amount of disruption to the project activities. State maintenance forces will be responsible for all traffic control at their work site. All costs for providing the mix, including the asphalt cement, shall be included in the unit price bid for "Hot Bituminous Mix Supplied."

409 P01 The 4½" class 27 hot bituminous pavement shall be paver laid in two approximately equal lifts.

NOTE SHEET

N JCT ND 13 TO JCT ND 46

BLENDED BASE AND HOT BIT PVMT

NOTE

r:\project\20001033.025\d_paving\n Mar. 12, 1997 17:14:52

ESTIMATE OF QUANTITIES

FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	SS-2-001(025)033 I-2-J001-94292	5

REVISED 03/10/1997

SPEC	CODE	ITEM DESCRIPTION	UNIT	MAINLINE	7) FLARED INTERSECTION	10)SL APPR 25) PD APPR	HOT BIT MIX SUPPLIED	TOTAL
103	0100	CONTRACT BOND	L SUM	1				1
202	0105	REMOVAL OF STRUCTURE	L SUM	1				1
202	0289	REMOVE APPROACH	EA	1				1
203	0180	ROADWAY OBLITERATION	LF	1,250				1,250
203	0207	APPROACH INSLOPE RECONSTRUCTION	EA	72				72
216	0100	WATER	M GAL	7,584	325	45		7,954
230	0165	SUBGRADE PREPARATION-TYPE A-12IN	STA	100				100
234	0104	HYDRATED LIME	TON	109				109
302	0500	BLENDED BASE COURSE	SY	409,437	8,961	13,052		431,450
401	0100	MC70 OR 250 LIQUID ASPHALT	GAL	77,579	1,865	2,621		82,065
401	0152	SS1H OR CSS1H EMULSIFIED ASPHALT	GAL	33,941	804	532		35,277
401	0160	BLOTTER MATERIAL CL 44	TON	1,543	24	59		1,626
402	9000	LIQUID BASE STABILIZER	GAL	175				175
408	0199	HOT BITUMINOUS MIX SUPPLIED	TON				9,000	9,000
409	0227	HOT BITUMINOUS PAVEMENT QC/QA CL 27	TON	79,910	2,243	1,543		83,696
409	0320	120-150 ASPHALT CEMENT	TON	4,628	130	79		4,837
409	0900	TESTING	TON	79,910				79,910
409	0910	CORED SAMPLE	EA	392				392
550	2040	PORTLAND CEMENT	TON	146				146
702	0100	MOBILIZATION	L SUM	1				1
704	0100	FLAGGING	MHR	1,000				1,000
704	1000	TRAFFIC CONTROL SIGNS	UNIT	1,938				1,938
704	1052	TYPE III BARRICADE	EA	2				2
704	1060	DELINEATOR DRUMS	EA	32				32
704	1185	PILOT CAR	HR	300				300
706	0300	FIELD LABORATORY-TYPE C	EA	2				2
714	5015	PIPE CORR STEEL .064IN 18IN	LF	2,000				2,000
714	5035	PIPE CORR STEEL .064IN 24IN	LF	53				53
714	5810	END SECT CORR STEEL .064IN 18IN	EA	174				174
714	5820	END SECT CORR STEEL .064IN 24IN	EA	4				4
714	9660	REMOVE & RELAY END SECTION-ALL TYPE & SIZES	EA	2				2
720	0110	RIGHT OF WAY MARKERS	EA	106				106
754	0116	FLAT SHEET FOR SIGNS-TYPE 2 REFL SHEETING	SF	150				150

ESTIMATE NUMBER: 892 RUN DATE: 03/12/1997 TIME: 17:20:58

c:\design\quansht.dgn Jan. 08, 1997 15:25:26

ESTIMATE OF QUANTITIES

FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	SS-2-001(025)033 I-2-J001-94292	6

REVISED 03/10/1997

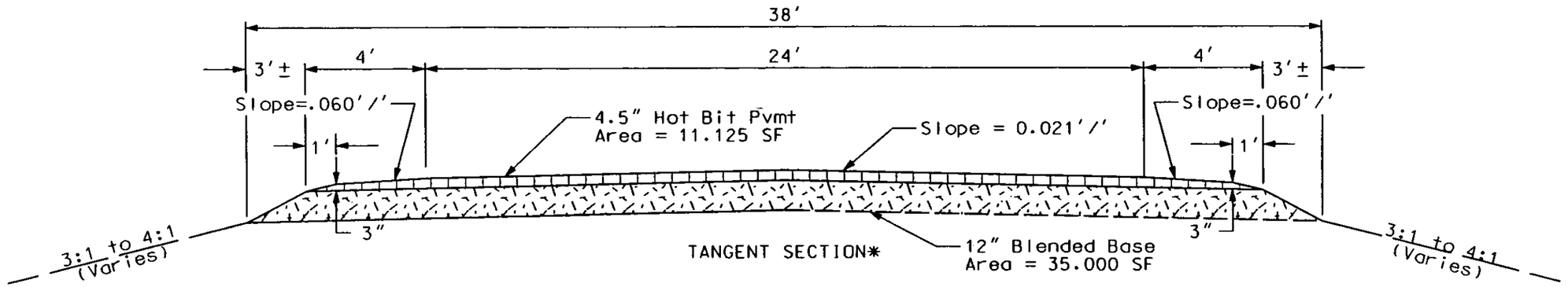
SPEC	CODE	ITEM DESCRIPTION	UNIT	MAINLINE	7) FLARED INTERSECTION	10)SL APPR 25) PD APPR	HOT BIT MIX SUPPLIED	TOTAL
754	0117	FLAT SHEET FOR SIGNS-TYPE 3A REFL SHEETING	SF	13				13
754	0206	STEEL GALV POSTS-TELESCOPING PERFORATED TUBE	LF	268				268
754	0319	HAZARD MARKERS-TYPE III	EA	32				32
762	0405	SHORT TERM 4IN BROKEN LINE-PNT TAPE OR RSD MRK	LF	48,486				48,486
762	0410	SHORT TERM 4IN LINE NPZ-PN TP OR RS MRK	LF	48,486				48,486
762	1104	PVMT MK PAINTED 4IN LINE	LF	242,433	9,100			251,533
762	1108	PVMT MK PAINTED 8IN LINE	LF	168				168
766	0100	MAILBOX-ALL TYPES	EA	18				18
770	0020	CONCRETE FOUNDATION-HIGHWAY LIGHTING	EA	3				3
770	0220	CABLE TRENCH-TYPE II	LF	349				349
770	0330	2IN DIAMETER RIGID CONDUIT	LF	263				263
770	0445	MULTIPLE UNDERGROUND CABLE 3NO6 STYLE USE	LF	658				658
770	1678	LT STD 6FT MA 42FT POLE BREAKAWAY	EA	3				3
770	4120	HP SODIUM VAPOR LUMINAIRE-150 WATT	EA	3				3

ESTIMATE NUMBER: 892 RUN DATE: 03/12/1997 TIME: 17:20:58

c:\design\quansht.dgn Jan. 08, 1997 15:25:26

FHWA REGION	STATE	PROJECT NO.	SHEET NO.
8	ND	SS-2-001(025)033	9

REVISED 03/10/1997



*Curve Section same as Tangent Section except for superelevation.

See Note 302/P02 for locations of Experimental Base Stabilizing Agents.

BASIS OF ESTIMATE

DESCRIPTION	UNITS	QUANTITY PER MILE	WIDTH
Water for Dust Palliative @ 25 MGal/Mile and for Blended Base @ 20 Gal/Ton	MGal	447	
Blended Base Course (existing Pavement and existing Aggregate Base)	SY	22,293	38'
MC-70 or 250 Liq Asph for Prime Coat @ 0.20 Gal/SY (top of Blended Base Course)	Gal	4,224	36'
Blotter Material Cl 44 @ 12 Lbs/SY for Prime Coat Maintenance	Tons	84	24'
SS-1h or CSS-1h Emuls Asph for Tack Coat @ 0.05 Gal/SY (top of Blended Base)	Gal	939	32'
SS-1h or CSS-1h Emuls Asph for Tack Coat @0.05 Gal/SY (between lifts)	Gal	909	31'
Class 27 Hot Bit Pvmt @ 2.0 Ton/CY	Tons	4,351	30'
120-150 Asph Cement for Cl 27 Hot Bit Pvmt @ 5.8% of Cl 27 Hot Bit Pvmt	Tons	252	

PROPOSED TYPICAL SECTION
AND BASIS OF ESTIMATE
STA 477+45.9 to 1114+13.3 BK=
STA 0+00 AHD to 333+06

N JCT ND 13 TO JCT ND 46

BLENDED BASE AND HOT BIT PVMT

TP47745

r:\project\20001033.025\d_paving\t Mar. 11, 1997 08:36:19

Appendix B

Highway 1

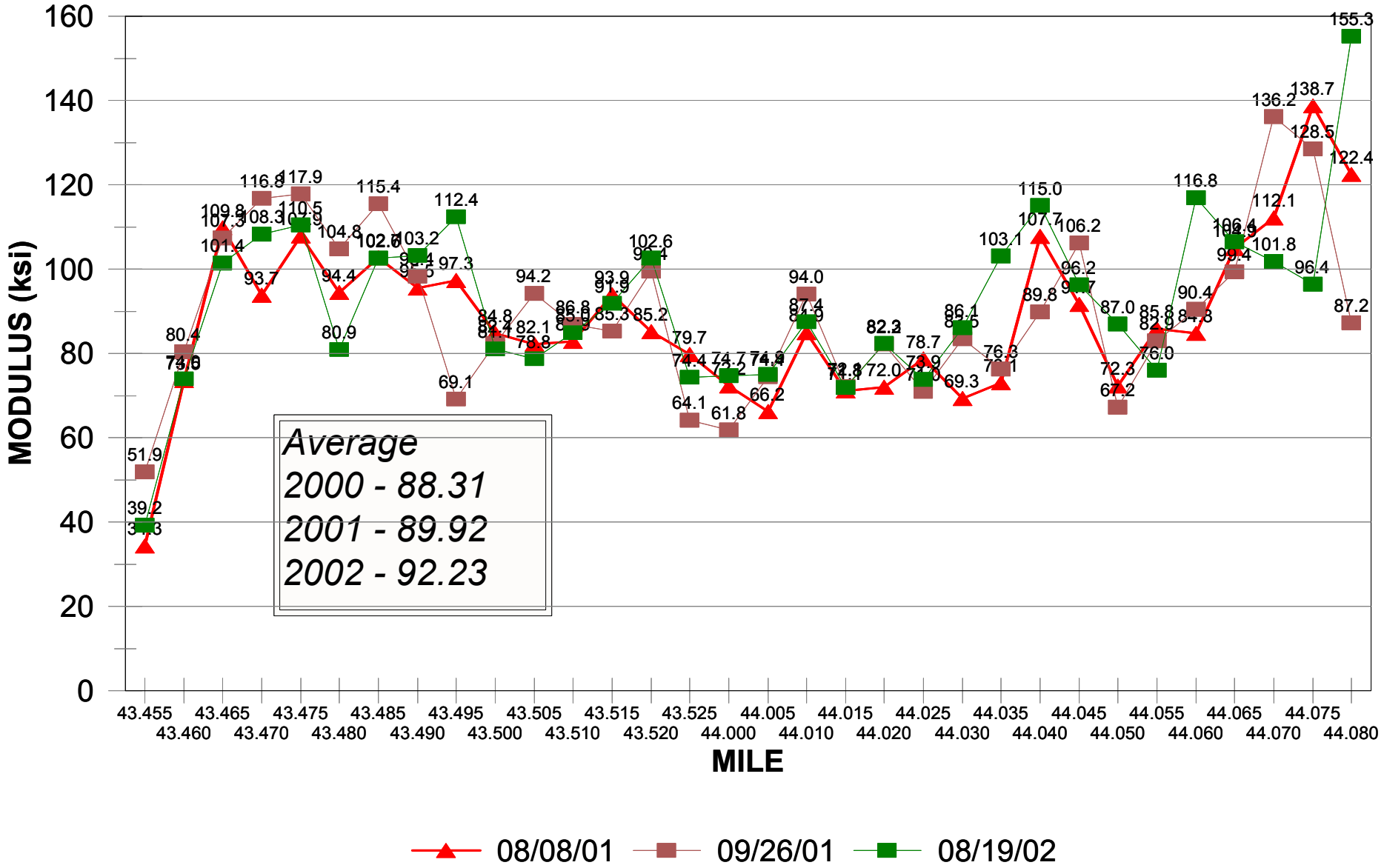
		08/08/00	09/26/01	08/19/02
	MILE	**AVE**	**AVE**	**AVE**
	Lime	88.31	89.92	92.23
	Cement	88.26	105.78	102.49
	Consolid	35.55	41.18	36.37
	Control	39.11	40.99	39.51
	PROJ AVE	63.22	69.80	68.05
	STD DEV	29.48	33.48	34.26
Mile	**TESTLOC**	**E2**	**E2**	**E2**
Lime	43.4550	34.31	51.91	39.22
Lime	43.4600	73.55	80.35	73.99
Lime	43.4650	109.78	107.30	101.44
Lime	43.4700	93.75	116.80	108.28
Lime	43.4750	107.93	117.86	110.48
Lime	43.4800	94.44	104.78	80.93
Lime	43.4850	102.66	115.42	102.55
Lime	43.4900	95.55	98.38	103.24
Lime	43.4950	97.27	69.14	112.40
Lime	43.5000	84.79	82.38	81.09
Lime	43.5050	82.14	94.17	78.77
Lime	43.5100	82.88	86.80	84.96
Lime	43.5150	93.90	85.26	91.89
Lime	43.5200	85.22	99.42	102.58
Lime	43.5250	79.73	64.13	74.36
Lime	44.0000	72.23	61.80	74.67
Lime	44.0050	66.19	74.41	74.94
Lime	44.0100	84.91	94.04	87.43
Lime	44.0150	71.06	72.13	71.83
Lime	44.0200	72.00	82.21	82.26
Lime	44.0250	78.72	71.03	73.86
Lime	44.0300	69.28	83.53	86.06
Lime	44.0350	73.08	76.30	103.12
Lime	44.0400	107.73	89.79	115.04
Lime	44.0450	91.66	106.19	96.23
Lime	44.0500	72.32	67.22	86.95
Lime	44.0550	85.76	82.93	75.98
Lime	44.0600	84.83	90.45	116.85
Lime	44.0650	104.87	99.39	106.43
Lime	44.0700	112.07	136.18	101.82
Lime	44.0750	138.74	128.54	96.40
Lime	44.0800	122.42	87.22	155.29
Cement	44.0850	94.26	141.98	94.03
Cement	44.0900	104.41	123.27	118.38
Cement	44.0950	110.24	90.23	97.08
Cement	44.1000	52.65	78.74	87.62
Cement	44.1050	81.39	100.35	112.95
Cement	44.1100	92.50	108.19	120.24
Cement	44.1150	92.04	109.14	113.79
Cement	44.1200	128.26	123.67	105.98
Cement	44.1250	97.71	162.76	135.82
Cement	44.1300	89.39	122.15	134.74
Cement	44.1350	105.09	129.00	141.04
Cement	44.1400	127.66	172.70	123.52
Cement	44.1450	79.43	93.42	115.60
Cement	44.1500	85.85	108.34	132.14
Cement	44.1550	86.63	104.00	93.21
Cement	44.1600	76.54	85.81	90.63
Cement	44.1650	79.69	96.46	93.77

Cement	44.1700	87.20	99.86	75.39
Cement	44.1750	100.58	93.12	106.71
Cement	44.1800	105.35	89.13	79.15
Cement	44.1850	77.03	88.42	126.82
Cement	44.1900	101.19	102.25	115.38
Cement	44.1950	88.66	129.19	96.34
Cement	44.2000	97.03	114.85	111.02
Cement	44.2050	94.35	94.25	99.47
Cement	44.2100	92.50	108.42	110.87
Cement	44.2150	67.55	108.08	101.10
Cement	44.2200	61.41	98.64	66.92
Cement	44.2250	61.24	59.26	35.57
Cement	44.2300	29.89	37.70	39.43
Consolid	44.2350	33.17	42.51	36.92
Consolid	44.2400	42.56	37.19	32.09
Consolid	44.2450	27.52	40.14	34.45
Consolid	44.2500	27.79	39.16	31.75
Consolid	44.2550	33.48	34.66	31.88
Consolid	44.2600	29.44	38.84	36.06
Consolid	44.2650	36.45	38.80	38.26
Consolid	44.2700	32.18	48.37	35.03
Consolid	44.2750	44.23	51.40	45.03
Consolid	44.2800	42.46	44.71	40.81
Consolid	44.2850	39.94	41.87	40.12
Consolid	44.2900	39.14	42.28	40.34
Consolid	44.2950	42.28	44.10	40.77
Consolid	44.3000	44.57	46.73	39.22
Consolid	44.3050	36.32	45.79	37.74
Consolid	44.3100	31.71	42.14	32.41
Consolid	44.3150	34.08	40.39	28.36
Consolid	44.3200	31.64	37.86	30.67
Consolid	44.3250	29.69	36.83	32.79
Consolid	44.3300	27.55	33.13	35.05
Consolid	44.3350	28.66	36.23	28.15
Consolid	44.3400	34.98	40.30	33.55
Consolid	44.3450	32.93	41.64	37.42
Consolid	44.3500	41.55	44.79	39.95
Consolid	44.3550	31.39	38.33	28.05
Consolid	44.3600	37.43	40.71	37.19
Consolid	44.3650	38.22	40.10	41.49
Consolid	44.3700	34.25	35.24	34.43
Consolid	44.3750	30.08	35.84	36.67
Consolid	44.3800	50.82	55.26	54.36
Control	44.3849	39.84	38.64	40.88
Control	44.3900	40.49	42.58	37.28
Control	44.3950	46.08	42.16	43.26
Control	44.4000	39.64	47.05	42.30
Control	44.4050	45.16	42.15	39.76
Control	44.4100	37.56	41.13	41.67
Control	44.4150	37.27	38.00	36.10
Control	44.4200	43.44	44.08	42.63
Control	44.4250	44.57	46.01	44.99
Control	44.4300	36.02	38.30	33.70
Control	44.4350	35.67	41.10	40.69
Control	44.4400	40.62	41.73	35.00
Control	44.4450	32.25	40.29	38.96
Control	44.4500	48.43	45.68	56.48
Control	44.4550	46.14	46.41	45.62
Control	44.4600	34.03	34.82	31.33
Control	44.4650	33.94	35.71	33.48

Control	44.4700	37.90	39.49	37.90
Control	44.4750	34.48	32.68	31.59
Control	44.4800	36.35	44.21	40.69
Control	44.4850	37.00	32.06	35.36
Control	44.4900	31.54	27.81	32.27
Control	44.4950	27.47	32.94	29.82
Control	44.5000	37.30	35.23	37.50
Control	44.5050	30.17	37.55	31.69
Control	44.5100	41.95	43.50	43.01
Control	44.5150	41.64	49.35	39.48
Control	44.5200	42.61	51.25	47.88
Control	44.5250	47.81	50.90	49.75
Control	45.0000	45.93	46.85	44.35

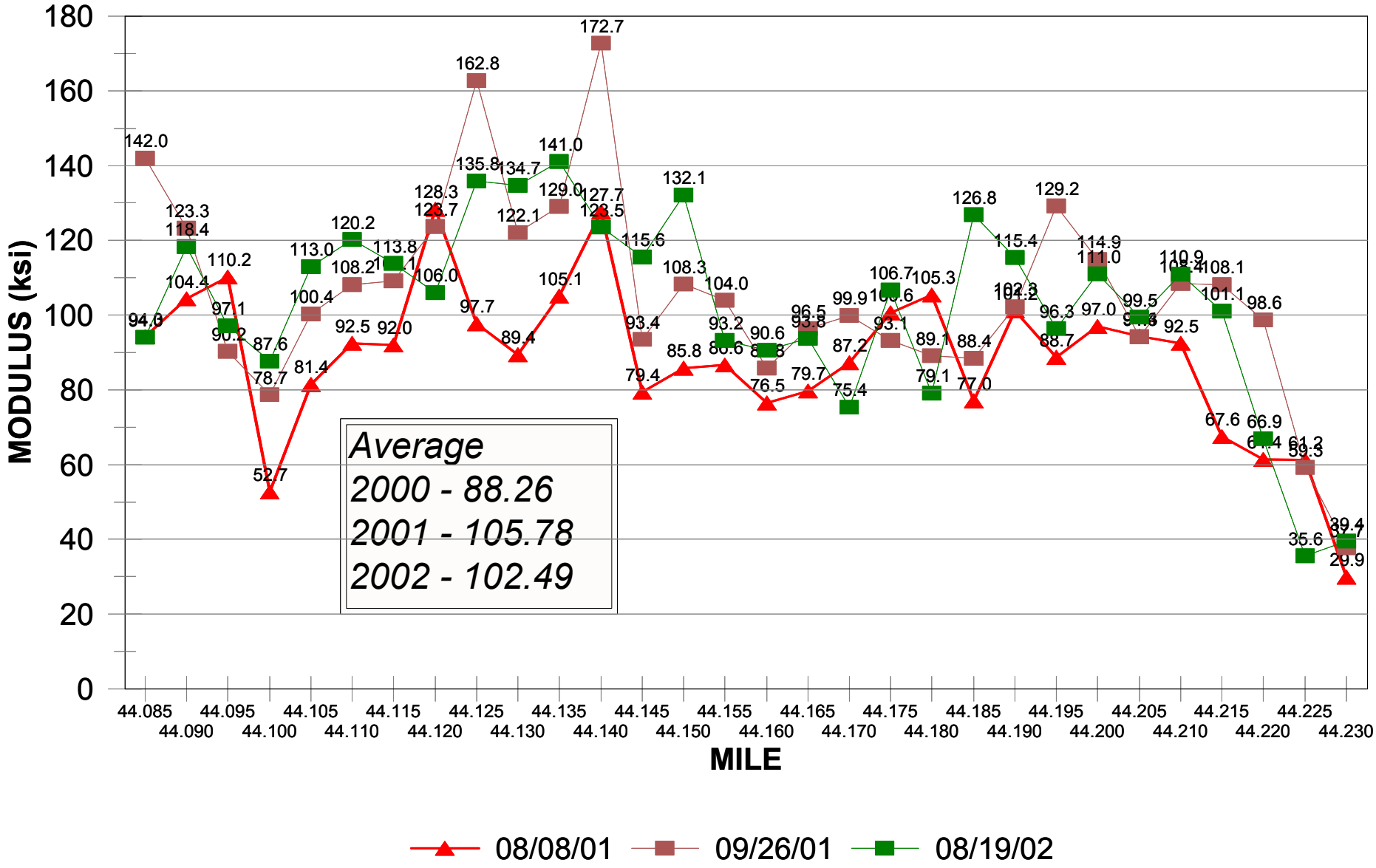
MR 97-02

Lime Section



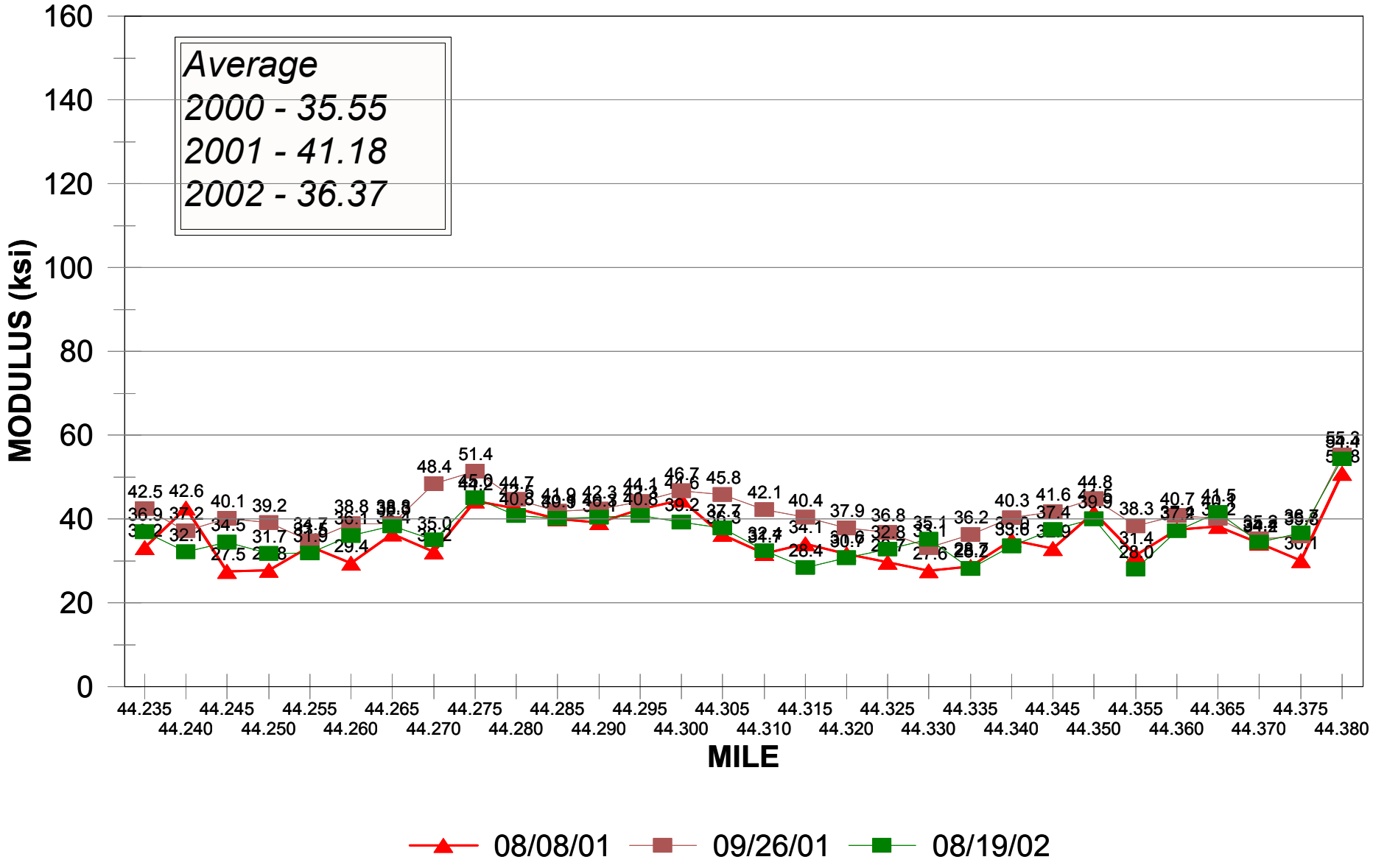
MR 97-02

Cement Section



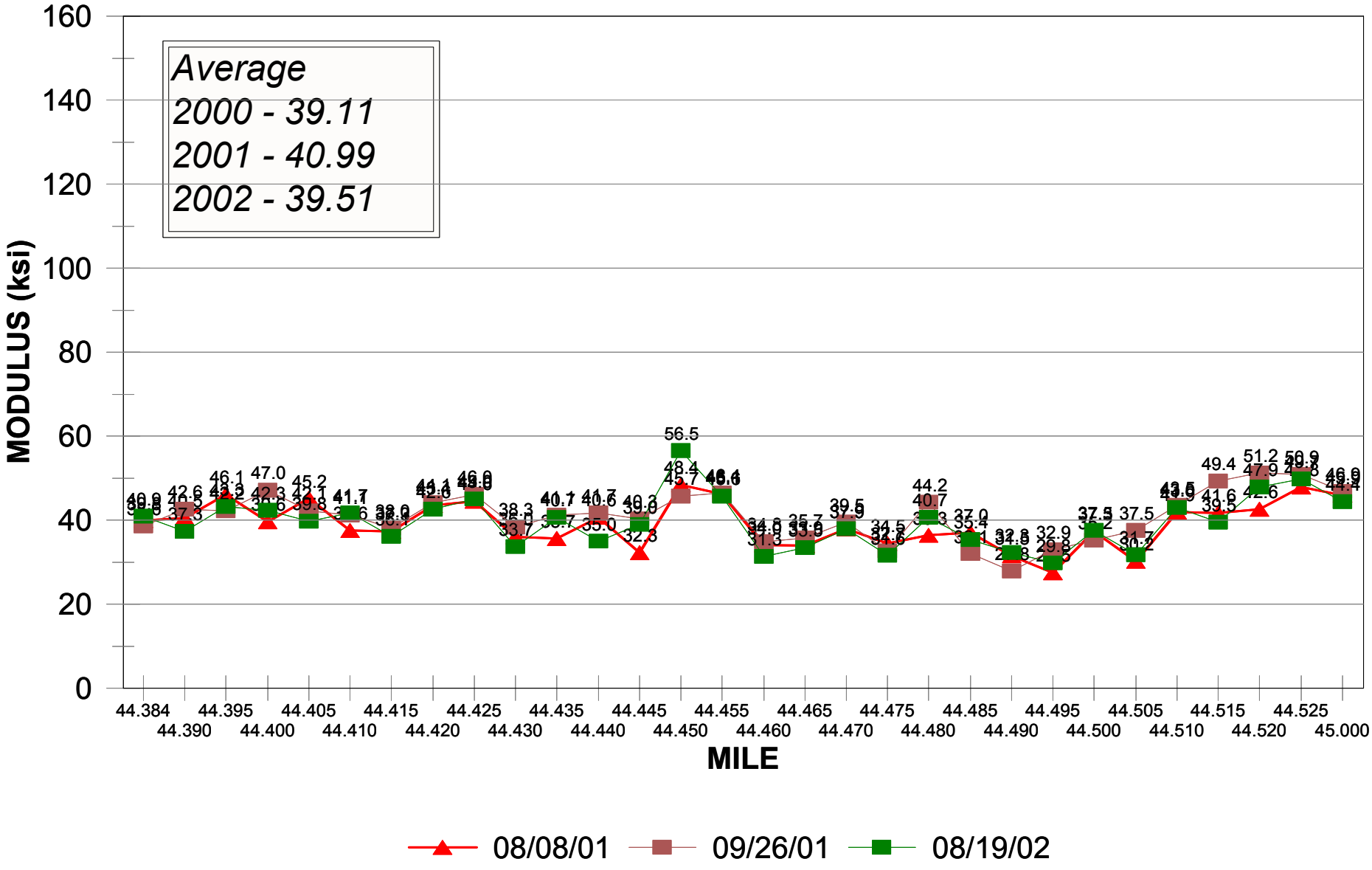
MR 97-02

Consolid Section



MR 97-02

Control Section



Appendix C

american consolid inc.

502 E. 32nd Street - Davenport, Iowa 52803 - Phone/Fax: ~~319~~-323-4464
563

March 26, 2002

Mr. Bryon Fuchs
North Dakota Department of Transportation
Materials & Research Division
300 Airport Road
Bismarck, North Dakota 58504

Dear Mr. Fuchs:

In response to your telephone call and Fax of March 20, 2002, I am enclosing several sheets of information about the Consolid System. I hope they contain the information you require to evaluate the test sections done in 1998.

If you decide you wish to use the Consolid System on another section of road or highway please contact our affiliate in Canada:

Mr. David Lunn
Consolid Canada Inc.
#1 1715 27th Avenue N. E.
Calgary, Alberta T2E 7E1
Canada

Telephone – 403-938-4347
FAX – 403-938-4036

Mr. Lunn has the Consolid 444 and Conservex available in the amounts necessary for any project you may wish to undertake, as well as the knowledge, background and experience to provide excellent service.

Sincerely,

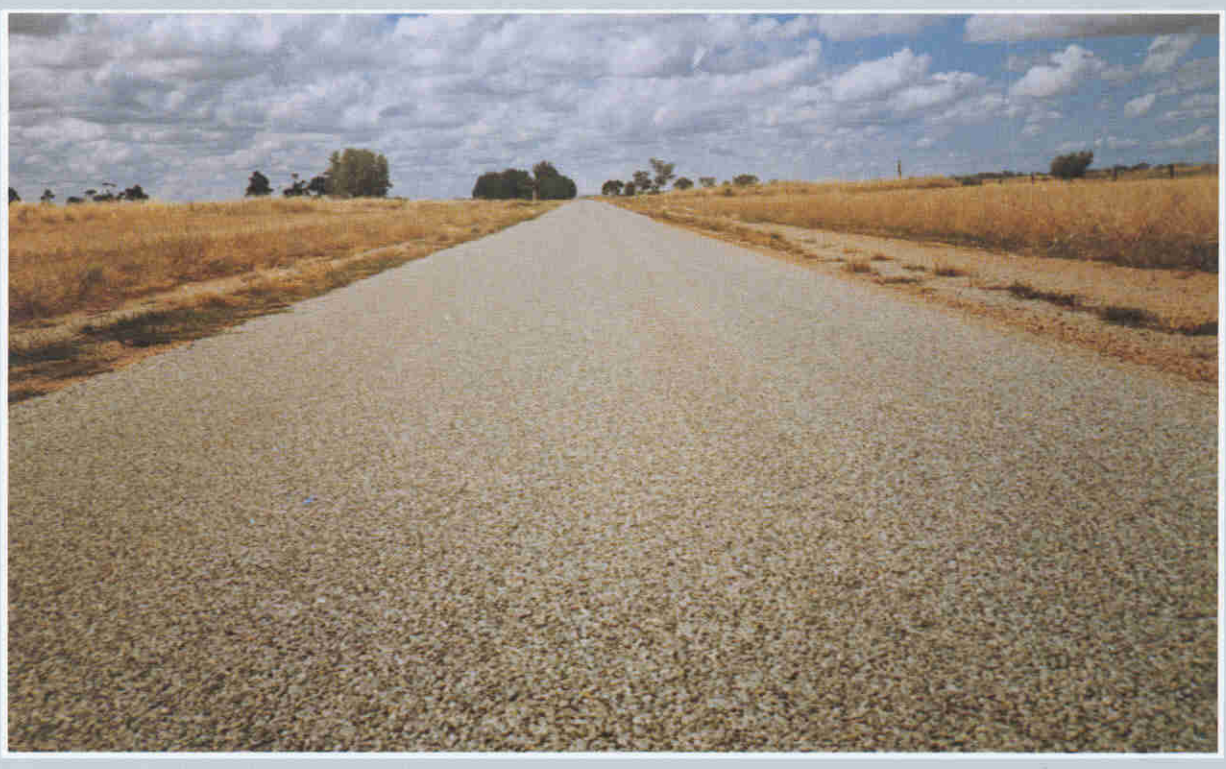
Nandora M. Raiford

Nandora M. Raiford
President

INTRODUCING the new system for soil stabilization in road construction - make your road dollars go twice as far

THE CONSOLID SYSTEM

Roads, road shoulders, air fields, parking lots, drive-ways, walkways, playgrounds and bicycle paths.



What is THE CONSOLID SYSTEM?

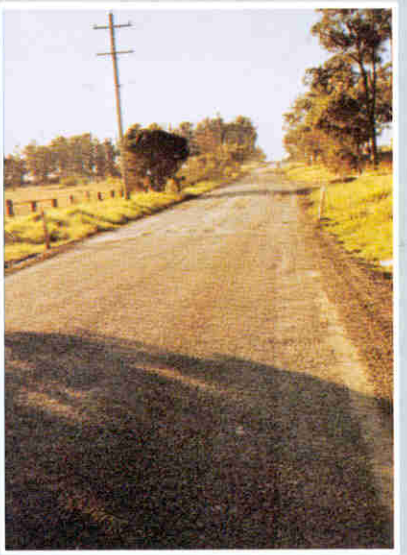
The Consolid System uses two combinations of soil additives; one, a combination of inverted emulsions and the other a combination of an inverted emulsion and a lime hydrate based powder.

Consolid 444 removes water from the soil infra structure and creates a strong bond between the soil particles. Conservex, used for dryer soils, is then mixed in and blocks any air voids to water entry, thus providing a water resistant finish. If the soil is, by nature, very moist, Solidry is used in place of Conservex, performing the same purpose in water resisting and soil strengthening. These three components give the Consolid System two combinations to cover the entire field of soil stabilization — Consolid 444 + Conservex or Consolid 444 + Solidry.

Advantages and benefits of THE CONSOLID SYSTEM

1. In situ treatment of the soil eliminates costly material transfer.
2. The treated soil is highly resistant to water attack, reducing surface cracking and maintenance costs.
3. Application of the products is quick and easy requiring no specialized equipment.
4. The chemicals and applications are non-toxic and non-polluting.
5. Cost savings can approach 50% over conventional road construction practices.

Untreated road



Treated and untreated road

Final treated road

Historical background

In the 1960's, Dr. G.A. Scherr of Consolid A.G. (Switzerland) developed and manufactured a special asphalt emulsion to be used in road construction. After years of refinement and use, the Consolid System has won acceptance in many countries throughout Europe, the Middle East, Asia and South America. Now this new technology for road construction is available in the United States with the incorporation of American Consolid Inc.

Discover how to stretch your money "down the road". Contact:

american consolid inc.

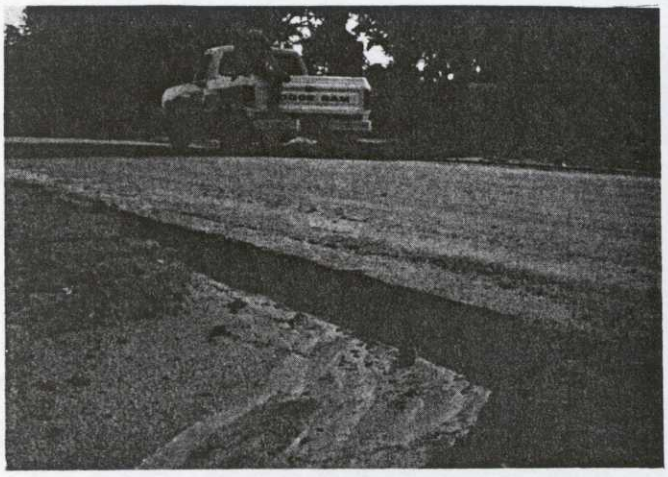
606 KAHL BUILDING • DAVENPORT, IA 52801 • PHONE: 319-322-2727 • 1-800-373-8143 • FAX 319-322-6241

The CONSOLID™ System of Basecourse Construction

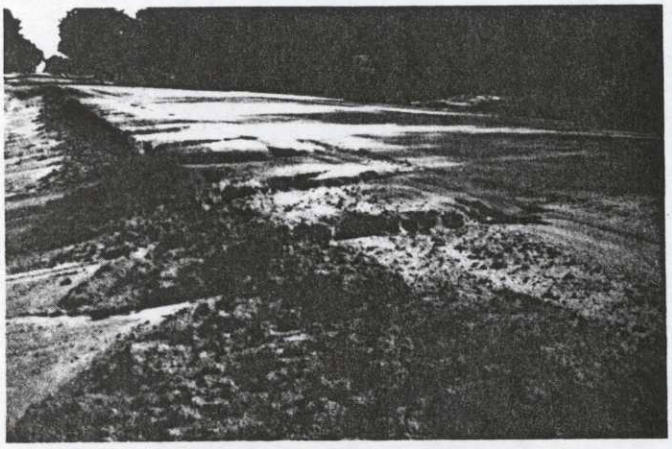
During the course of construction of the Chesser-Monroe Road in Putnam County, Florida, the County encountered severe rains, 6 inches in a 24 hour period. Usually when this much rain occurs, an untreated earthen road will experience severe erosion. Large ruts and ruptures are caused along with nightmarish washouts. But when the CONSOLID™ System of basecourse construction is used, the treated and stabilized soil becomes a permanent, water resistive basecourse that can withstand and resist these problems.

Because the CONSOLID™ System agglomerates the soil's fine particles, the voids and capilliaries are eliminated, thus the water is not allowed to penetrate and destroy the base. The treated soil will be able to maintain its strength and integrity, even under extremely wet conditions.

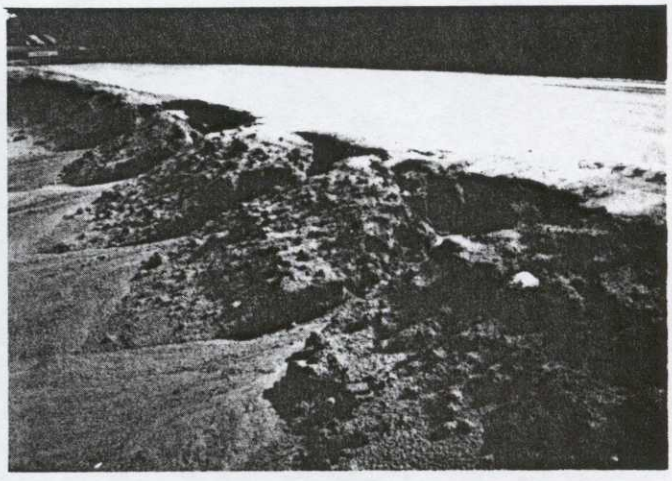
The CONSOLID™ System is designed to work in any soil containing a 20% minimum fines content (that material passing a No. 200 sieve).



Here you can clearly see where the untreated basecourse was washed away.



Another example of the CONSOLID™ System's stabilized base versus the untreated shoulder.



For more information on the CONSOLID™ System and how it can help your road construction program, please contact:

AMERICAN CONSOLID INC.
502 E. 32ND ST.
DAVENPORT, IOWA 52803
(319) 323-4464

american consolid inc.
502 E. 32nd Street - Davenport, Iowa 52803 - Phone/Fax: 319-323-4464

THE CONSOLID SYSTEM
QUESTIONS AND ANSWERS

1. What is SOIL STABILIZATION?

   "Soil Stabilization" results when an in situ soil is made usable for risk-free application for any and all earthwork. This is distingishable from "soil improvement" which is a very small increase in the quality, and in particular, the workability of a soil. "Soil Stabilization" actually changes the properties of the soil.

2. What are the advantages of the CONSOLID SYSTEM?

   The CONSOLID SYSTEM, consisting of the combinations CONSOLID 444/ CONSERVEX and CONSOLID 444/SOLIDRY, was developed particularly for the purpose of soil stabilization.

   Every cohesive soil has the ability to petrify; all that is required is a very very long time and a very very high pressure. However, this process can be sped up considerably. If the soil can be activated by catalysts or pseudo-catalysts towards this process, a considerable improvement can be achieved for almost any soil. This is the CONSOLID SYSTEM.

   The application of CONSOLID 444 causes an irreversible agglomeration of the soil's fine particles, thus reducing surface area and destroying the adhering water film. The water content of the soil, especially its capillary saturation, will be highly reduced or slowed down. An additional treatment of CONSERVEX and SOLIDRY protects the stabilized soil from water.

3. What types of soils can be treated with the CONSOLID SYSTEM?

   In principal, all types of cohesive or semi-cohesive soils can be treated with the CONSOLID SYSTEM. The degree of stabilization will be determined by the type of soil. The major requirement for the soil however, is mixability. Very heavy, sticky clays can be difficult to mix and should be mixed with sand to improve overall mixability with the stabilizers.

4. How are non-cohesive soils (sand) treated with the CONSOLID SYSTEM?

   Because the CONSOLID products work with the cohesive soil particles which contain natural binders, a soil containing an overabundance of sand must be mixed, prior to treatment with CONSOLID additives, with a cohesive soil to obtain a silt/clay mixture of 20%.

FOR ROAD CONSTRUCTION

Certain types of soil can be used successfully in building subbases and basecourses as foundations for a wear course in road construction. This soil must however fulfill very strict quality parameters because the high strength and loading capacity must come from these layers.

The best material is one which has little or no fines which would reduce the quality of a sandy or woarse construction material substantially due to the sensitivity of those fines against water. Such a construction material must be carefully prepared and selected from resources which are becoming more scarce. In the past, much of these materials were wasted before it was realized that the supply was not endless.

In order to obtain such a high tonnage to satisfy the demand, lower quality materials must be upgraded to meet the specifications of higher quality material. Unfortunately, this process requires a costly investment in both time and money, and still more waste is generated. To avoid this costly treatment of low quality material, it is possible to treat the material and bring it up to an acceptable standard. Through the proper use of stabilization additives, the material's fines can be brought under control, reducing waste and its impact on the environment. This will also result in lower costs and better material for road and street construction.

We at CONSOLID have concentrated the research and development of our CONSOLID additives to give maximum benefit to many different soil types in many varying conditions. By controlling the water sensitivity of the soil's fine particles, the stability of the soil can remain intact.

ROAD CONSTRUCTION, REHABILITATION AND MAINTENANCE

Roads are seldom destroyed from the top down; they disintegrate from the bottom. This is the reason that repairs are so expensive. It is extremely costly to repair a failed road when it has to be rebuilt from the ground up. All this can be prevented, however, by stabilizing the foundation layers (sub-grade, subbase and basecourse) with Consolid System additives. A relatively low investment will result in not only substantial improvements, but also cost savings. Read along and discover the advantages.

NEW ROAD CONSTRUCTION

The Consolid System additives can up-grade almost any in situ soil for road construction and bring the soil's undesirable characteristics under control. The combinations of Consolid 444 and Conservex and Consolid 444 and Solidry will stabilize and consolidate almost 100% of all workable soils to a risk-free construction material. The shortage of high quality construction material for conventionally built roads is increasing. This material is not only difficult to find but it is also becomming increasingly more expensive to produce.

Low grade soils can meet foundation requirements only when their performance can be substantially and permanently improved. The Consolid System will up-grade the in place soil in most cases to obtain the required loading, capacity, density and stability. The soil's strength is directly related to the Consolid additives' ability to reduce the fines' tendency to absorb water. Because the presence of water is discouraged, frost damage is minimal in winter and spring freeze/thaw cycles. Soaked C.B.R. values increase an average of 3 to 5 times using the Consolid System over an untreated soil.

The in situ soil is treated and mixed "in place". In other words, the Consolid System additives are simply applied and mixed into the soil base-course using simple construction equipment such as water tanks, pulverizers and compaction rollers. The process can be interrupted at any time for changes in weather or construction process.

It is also possible to pre-mix the Consolid System additives in the soil "in plant" and to stock-pile the mixture until it is needed. Stockpiling does not harm the effectiveness of the treatment. Once the soil is treated, it remains treated. Gravel pits can prepare special mixtures for subbase, sub-grade and basecourse layers. This speeds up construction greatly and reduces equipment making the construction site safer.

Constructing a base with Consolid additives can reduce the cost of a newly constructed road up to 40%. Stabilizing the soil eliminates the need to remove and haul poor quality soil and haul in crushed rock to build a proper base.

ROAD REHABILITATION

Road recycling has become a very popular means of rehabilitating failed surfaces. Worn-out roads are reconstructed by using most of the existing foundation and material for the new construction.

Roads wear out from the top, but the most severe deformation and destruction comes from the foundation layers. Recycling the wearing course alone will not totally correct the problem unless the sub-base and basecourse are improved and fully stabilized.

It is extremely expensive to exchange the material conventionally; the old subbase/basecourse must be dug out, disposed of and replaced by new, borrowed material. There is a more economical solution however. Using the Consolid System with the existing base material, a stabilized and permanently treated foundation can be constructed at a cost far less than any other method.

Stabilization with the Consolid System improves the basecourse substantially and makes it possible to reduce the depth of the wear surface (asphalt paving). This results in reduced costs, in most cases in the range between 20% to 50%.

The shoulders should be included inthe stabilization process because soft shoulders often lead to underwashing and the destruction of the pavement. Soft shoulders that have washed away also can lead to accidents and serious injury.

This same rehabilitation process can be used for railway foundations. Stabilization of the existing embankment material can eliminate the softening and dissappearance of the ballast aggregate underneath the tracks.

ROAD MAINTENANCE

An asphalt or concrete wear surface will last much longer when installed over a stabilized basecourse. The basecourse is the load bearing material for the road and helps to bridge the heavy loads. The expensive wear surface does not have to perform both functions exclusively, allowing it to perform better and longer. Most any road can be made completely dust-free by simply stabilizing the basecourse and sealing it with the time honored surface of liquid asphalt and chips (in a single or double coat). Using this low cost surface, rural and agricultural roads, irrigation inspection roads and airstrips can be made dust-free, reducing soil erosion and crop damage by dusting. All of these aspects aid in preventing damage to our environment.

Rural roads, forest roads and footpaths left unsurfaced lead to soil erosion. The washed out material pollutes the land, blocks water channels and causes continuous damage resulting in substantial maintenance costs. Unprotected footpaths can destroy the environment through erosion and unintentional widening. Critical plant life and protected vegetation have all but disappeared from various parks throughout the world.

In both cases, the use of premixed stabilized soil can prevent this costly destruction. The material is erosion-proof, even when unsurfaced, which might be desirable for nature trails. If there is a need to avoid the mechanical grinding effect of the traffic, the treated basecourse can be easily and economically surfaced with a liquid asphalt and chips coating.

FOR MORE INFORMATION:

It is impossible to completely cover all the tremendous advantages of soil stabilization with the Consolid System. Please contact us and tell us of your specific soil problems. We will be pleased to work with you to solve these problems and show you how the Consolid System can effectively and economically solve your soil stabilization needs.

american consolid inc.

502 E. 32nd Street - Davenport, Iowa 52803 - Phone/Fax: 319-323-4464

SPECIFICATIONS AND APPLICATION PROCEDURE FOR CONSOLID 444 AND CONSERVEX IN ROAD, STREET, PARKING LOT, ETC. BASECOURSE CONSTRUCTION

1. SCOPE: Treatment of insitu clay/silt soil for standard 10 inch loosened soil depth for normal road basecourse construction with Consolid 444 and Conservex.
2. SUPERVISION: For first-time users, application of CONSOLID System chemical additives will be done under supervision of American Consolid Inc. engineer, representative, or contractor's trained supervisor familiar with the process.
3. MATERIALS:
   A. Consolid 444 Concentrate for application into a standard 10 inch loosened soil depth is always used at the rate of 0.0125 gallons per square yard. The concentrate is blended with water at 1:19, 1:14, 1:29, etc. depending upon the existing moisture content of the soil at time of application. For example, if the C444 Concentrate/ water blend is 1:29 the blended mixture would be applied at the rate of 0.375 gals. per square yard or 37 1/2 gals. per 100 square yards loosened soil depth.
   B. Conservex Concentrate for application into top half(5") of the 10" loosened soil depth, is also used at the rate of 0.0125 gals. per square yard. However, the concentrate is always blended with MC-30 or equal asphalt cut-back oil at the rate of 1:19. Therefore, the Conservex:MC-30 blend is applied at the rate of 0.25 gals. per square yard/5" of loosened soil depth, or 25 gals. per 100 square yards/5" depth.
4. PREPARATION, APPLICATION OF CONSOLID SYSTEM STABILIZATION ADDITIVES, AND CONSTRUCTION OF STANDARD 10" LOOSENED SOIL DEPTH BASECOURSE:
   NOTE: The following procedure is based on two(2) 5" lifts construction practice.
   A. Scarify to remove old surface of asphalt paving, oil and chips, large diameter rocks, etc.--or using a reclaimer/recycler machine grind into the soil basecourse to obtain 10" depth of loosened soil.
   B. Loosen/break-up soil to a depth to insure at least 10" of well loosened soil for area to be CONSOLID System treated. Soil particles, rocks, stones, pieces of asphalt or concrete present in the soil should not exceed 1 to 2 inches in diameter.
   C. Check grades desired and bring in additional similar quality soil, if required, and loosen.
   D. Check the Optimum Moisture Content(OMC) of the soil. A "rule of thumb" check would be if the soil can be squeezed into a ball with the hand. If it cannot, add water from a distributor tank truck or adjust the C444:Water blend upward to increase the water content of the soil slightly above the OMC.
   E. Windrow approximately 5" off to the side to treat the first lift.
   F. Using distributor tank truck with spray bar, apply C444 Concentrate:Water Blend as prepared under 3.A. above to give one-half(1/2) of the 0.0125 gals. of C444 Concentrate per square yard or 0.00625 gals. For example, if the blend is 1:29 as under 3.A. above, the application rate in the first lift would be 0.1875 gals./sq. yd. or 18.75 gals./100 sq.yds.
   Make sure the C444:Water Blend is evenly spread over the soil surface.
   G. Mix the Consolid 444:Water solution thoroughly into the soil be making several passes with disc harrow and grader or soil mixing equipment.
   H. Using a sheep's foot roller or multi-wheel roller at 750 pounds/sq. inch or greater of contact area pressure, compact the Consolid 444 treated soil by making several passes over the treated area.
   (Compaction is to be to a 95-98% Modified AASHTO Density.)
   I. Replace the 5" soil windrow back to the road surface.
   J. Repeat step 4.F. above with the addition of the C444:Water Blend applied to the top lift--again insuring that it is evenly spread over the soil surface.

K. Using the oil distributor tank truck with spray bar, apply the Conservex:MC-30 Cut-back solution prepared under 3.B. above at the rate 0.25 gals./sq. yd. or 25 gals./ 100 sq. yds. to the top lift.

L. Mix the Consolid 444 and Conservex thoroughly into the top 5" of loosened soil by making several passes with the soil mixing equipment or disc harrow and grader. Also, here a grader can be used in tandem with the disc harrow by "rolling" the soil to further aid thorough mixing.

M. Repeat Step 4.H. above.

N. Using grader, make "light depth" grading passes to level top surface and to adjust grade and crown of road basecourse.

O. Using a multi-wheel or flat face roller at 750 pounds per square inch or greater of contact area pressure, roll the CONSOLID System treated area by making several passes. (Compaction is to be to a 95-98% AASHTO Density.)

5. WEAR SURFACE APPLICATION:

A. If rain does not occur, after final flat face rolling the road basecourse can be opened to normal traffic, but 48 - 96 hours should elapse before applying the wear surface. If it rains before application of wear surface, allow road basecourse to dry out before applying wear surface.

B. For secondary type roads and streets, a wear surface or thin asphalt paving or liquid asphalt oil and chipped stone, pea gravel or sand can be used following standard application procedures.

C. For primary highways, roads, streets, etc. standard thickness of asphalt paving or concrete paving can be used as wear surface, if required by design engineer's specifications.

NOTE: The CONSOLID System treated in situ soil basecourse becomes the total load bearing constituent of the road when the wear surface is a thin overlay of asphalt paving or liquid asphalt oil and chipped stone, pea gravel and sand.

6. EQUIPMENT REQUIRED FOR CONSOLID SYSTEM STABILIZATION OF BASECOURSES:

Stabilization/consolidation of in situ soil for basecourse construction via the CONSOLID System uses standard road construction equipment as follows:

-scarifying machine
-soil breaking/pulverizing equipment
-grader with scarifier attachment
-water tank truck or tank trailer equipped with controllable volume spray bar and power take-off pump for application of Consolid 444:Water solution
-oil tank truck or tank trailer equipped with controllable volume spray bar and power take-off pump for application of Conservex:MC-30 Cut-back solution.
-tractor and large diameter disc harrow
-sheep's foot roller
-flat face vibratory roller
-multi-wheel roller/compactor

GENERAL NOTES: For light silty, clay soils and dependent upon type, weight of mixing and compacting equipment used, it is possible to CONSOLID System stabilize a 10" loosened soil basecourse in one lift instead of two lifts as stated above. This is done by treating the entire 10" with Consolid 444:Water solution, thoroughly mixing, compacting, and then treating the top half(5") with Conservex:MC-30 Cut-back Solution, thoroughly mixing into the top half(5") and again thoroughly compacting the total basecourse. Whether done in two lifts or one lift, crown and grade level of basecourse must always be respected.
Also, for light, silty, clay soils when motorized mixing or grinding equipment is not available usage of a tractor and large diameter disc harrow in tandem with a grader for "rolling over" the soil can be used. This method of mixing requires more time to achieve proper mixing since more passes must be made.